TROPOSPHERIC DIRECT CIRCULATIONS ASSOCIATED WITH THE CLIMATIC COMPONENTS OF SST VARIABILITY IN THE EQUATORIAL PACIFIC

David B. Enfield*
NOAA Atlantic Oceanographic & Meteorological Laboratory
Alberto Mestas-Nuñez
Cooperative Institute for Marine & Atmospheric Studies

## 1. INTRODUCTION

We know that El Niño-Southern Oscillation (ENSO) is associated with characteristic changes in the tropospheric direct circulation, comprised mainly of the zonal Walker and meridional Hadley circulations in the Pacific. Many of the observed tropical/subtropical rainfall fluctuations related to ENSO are directly explained by the strengthening or weakening that may occur in the convective or subsiding regions of the circulation. In some regions, attempts to use ENSO indices as rainfall predictors have met with mixed results, possibly due to the effects of decadal modes of variability, which may or may not reinforce the tropospheric response to ENSO. In this paper we investigate the modifying effects of decadal variability in the equatorial Pacific region where ENSO is strong, comparing the decadal effects with those of ENSO. Questions we address include: (1) Do the tropospheric circulation anomalies associated with decadal-scale warming in the NINO3 region reinforce the corresponding anomalies associated with superimposed ENSO warmings? (2) If the warm/cold associations for the two time scales are significantly different, how so and where, and what are the implications for climate predictions?

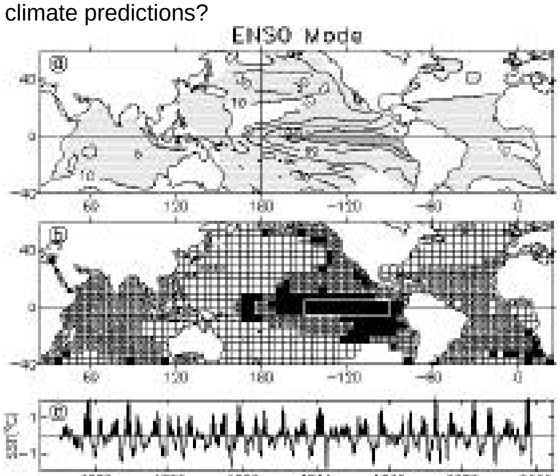


**Figure 1.** Global ENSO mode. Upper: spatially distributed gain with respect to the modal reconstruction (in the lower panel) for the NINO3 index region (white rectangle). Contours are 10, 30, 60 and 90 relative to 100 for NINO3. Middle: spatially distributed phase lag (3-month seasons) with respect to NINO3. A +/— indicates that the data lag/lead NINO3 by one season and numbers show phase shifts of more than one season. Lower: modal reconstruction for NINO3.

* *Corresponding author address*: David B. Enfield, NOAA Atlantic Oceanographic and Meteorological Laboratory, 4301 Rickenbacker Cswy, Miami, FL 33149; e-mail: enfield@aoml.noaa.gov.

## 2. DATA AND METHODS

Using an updated version of the Kaplan et al. (1998) SST dataset (1870-1998), we have constructed a global complex EOF mode of SST anomalies that reproduces the known canonical aspects of El Niño-Southern Oscillation (ENSO), including phase propagation of SST within and between ocean basins (Fig. 1; Enfield and Mestas-Nuñez, 1999).

When the global ENSO mode is subtracted from the data in the NINO3 region, we are left with a non-ENSO residual time series for SST anomalies that includes fluctuations from inter-seasonal to multidecadal time scales but is dominated the long time scales (Fig. 2). The global ENSO mode (middle) accounts for about 3/4 of the total SST anomaly variability (upper) while the residual (lower), accounts for the rest. Interestingly, about 40-50% of the amplitudes of the record-setting 1982-83 and 1997-98 El Niño events is accounted for by the residual variability. Related to this, the ranking of the canonical ENSO events changes significantly with respect to the NINO3 index based on data (e.g., 1972-73 is equal to or stronger than 1982-83 and 1997-98).

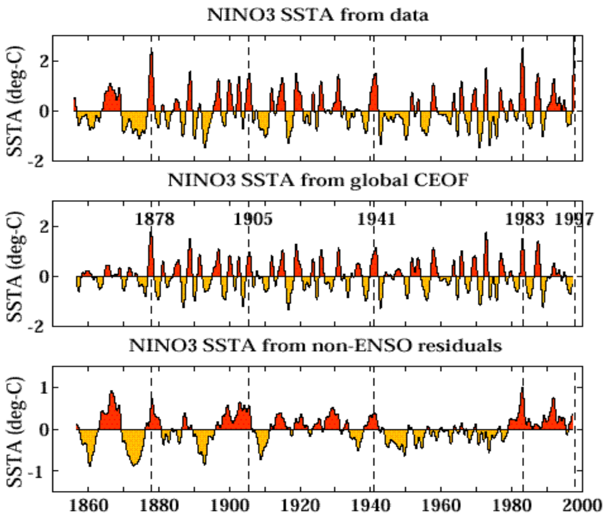


**Figure 2.** Decomposition of the area-averaged SSTA of the NINO3 region (upper) into its canonical ENSO (middle) and non-ENSO (lower) components. Some of the historically known events are highlighted with vertical lines.

Based on the indices of the canonical ENSO and residual (non-ENSO) variabilities in the NINO3 region (Fig. 2), we construct the associated boreal winter (DJF) global composite maps of the tropospheric direct circulation using the NCAR/NCEP reanalysis, 1950-99. The resulting maps of velocity potential and irrotational flow at 850 and 200 hPa, and vertical velocity at 500 hPa are compared with those for the climatological average for the 40 year period.

### 3. RESULTS

In our full paper (Mestas-Nuñez and Enfield, 2000), the above variables and tropospheric levels together show a consistent picture of the 3-D circulation for the normal DJF season as well as for its ENSO and decadal departures. Here we show only the velocity potential and irrotational flow at 200 hPa (Fig. 3), which makes an excellent proxy for the complete set of pictures.

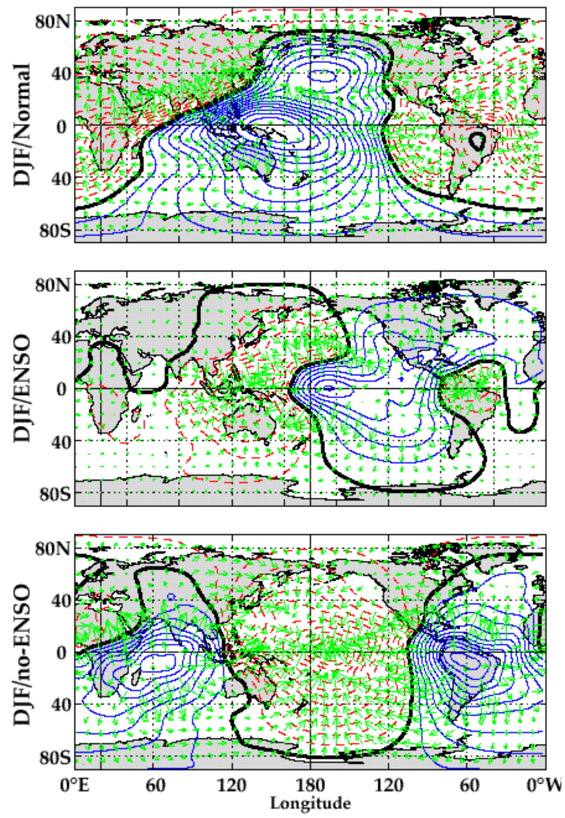


**Figure 3.** 200 hPa velocity potential (contours) and irrotational flow (arrows). Upper: the 40-year boreal winter mean. Middle: composite mean departures, for positive minus negative phases of the global ENSO mode. Middle: composite mean departures, for 1978-99 minus 1950-77, of the non-ENSO residual in the NINO3 region. Regions of high-level outflow (confluence) are indicated by diverging (converging) arrows and solid (dashed) contours. Hadley flows (or their departures) are indicated by regions of meridionally oriented arrows north of the equator.

The 50 year climatic mean (upper) shows the classical Walker and Hadley circulations. The anomalous boreal winter circulations, composited on the interannual (middle) and decadal (lower) components of the NINO3 variability, are quite different, from both climatology and from each other. They imply nearly opposite departures from the normal circulation, based on comparable warming phases within the NINO3 region:

- The zonal Walker circulations at low latitudes are virtually opposite, having decadal subsidence near the dateline in place of the ENSO-related uplift (convection), and decadal uplift over northern South America, in place of ENSO-related subsidence.
- In addition there occurs a decadal uplift over the Indian Ocean, where the ENSO anomaly pattern is featureless.

This implies a decadal enhancement of the Asian winter monsoon.

- Finally, we see a reversal of the meridional Hadley circulations into the subtropics of the Northern Hemisphere, for decadal warmings versus ENSO warmings, in both the Pacific and Atlantic sectors.

When ENSO warmings (or coolings) in the NINO3 region are superimposed on decadal anomalies of the same sign, the tropospheric direct circulation anomalies tend to counteract each other. The result can be to diminish or even reverse the ENSO-related climate anomalies in key regions such as northern South America and the Caribbean. If the superimposed ENSO and decadal components are OPPOSITE in sign (e.g., La Niña plus decadal warming), the ENSO teleconnections are decadally reinforced.

## 4. CONCLUSIONS

Our results indicate that the predictability of the tropospheric response to equatorial Pacific ENSO anomalies is enhanced when superimposed on a decadal SST anomaly of opposite sign, and diminished when of the same sign. In certain regions, at least, climate outlooks may be improved by separately analyzing the relationships between these SST anomaly components and their associated climate fluctuations. As an example, an empirical model of rainfall over Venezuela would be better served by a multiple regression of rainfall on the separate components of NINO3 (Fig. 2, middle and lower) than by a simple regression on the NINO3 index (Fig. 2, upper). Our community is now challenged to explain these relationships and assure that future prediction models properly account for them.

## 5. REFERENCES


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